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Multilevel Inverter Fed Switched Reluctance Motors (SRMs) 6/4, 8/6 and 10/8 SRM Geometric Types

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ABSTRACT

Nowadays power electronics circuits are embedded to most of electrical application areas. This approached offers a great control mechanism with simple and easy circuit configuration. Switched Reluctance Motor (SRM) is one of the most recent apparatus which draws a great number of researchers' interests. Previously several attempts are made to use the power converters as driver for SRM such as Voltage Source Inverter (VSI) and bridge converters. This paper presents an analysis study of three level inverter to control the SRM. The inverter is controlled using space vector modulation SVM. The aim of this paper is to report the use the multilevel inverter to be fed into the SRM. The implementation of the multilevel inverter is abl to reduce the Total Harmonics Distortion (THD). Performance comparison are made between the multilevel and previous power electronics circuits that applied to the SRM. The simulation results have been conducted by MATLAB/SIMULINK software.

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1. INTRODUCTION

In the electrical motors drive system, one of the most important parts is to design a driver circuit that can efficiently drive the motor to produce the desired output.In the case of the Switched Reluctance Motor (SRM) many researchers have focus on producing suitable drivers for the SRM [1]-[3]. Various type and construction of the SRM motor have been proposed which mainly a different in the employed phase, the number of stator/rotor poles used and torque production mechanism [2]. In this paper, three commonly type of SRM motors are used which can be distinguished by the number of phase. All the SRM motors however have similar parameters as shown in Table 1. All the SRMs are analyzed based on two different control mechanism which are power converter and multilevel inverter. The discussion are focused on the construction, control mechanism and performance comparison result.

Table 1. SRM Motor Parameters

Stator resistance (ohm)	0.01	Inertia (kg.m.m)	0.082
Frication (N.m.s)	0.01	Initial speed and position	[0 0]
Unaligned inductance(H)	0.67e-3	Aligned inductance (H)	23.6e-3
Saturated aligned inductance (H)	0.15e-3	Maximum current (A)	450
Maximum flux linkage (V.s)	0.486		

Figure 1(a) shows the basic and simplest type of SRM motor which has 6 stator poles and 4 rotor poles as the name given 6/4 SRM. The motion of this motor is produced due to the variable reluctance in the air gap between the stator and rotor windings. A single magnetic field is produced by the rotor winding activation. Then the torque is produced by the tendency of the rotor to move to its reluctance position. Figure 1(a) also illustrates the 6/4 SRM in the case of a rotor pole is aligned with a stator pole, due to the field lines are orthogonal to the surfaces there is no torque will be produced [4]. The difference between this motor and other types of motor construction is only the number of phased employed as well as the shape of the configuration.

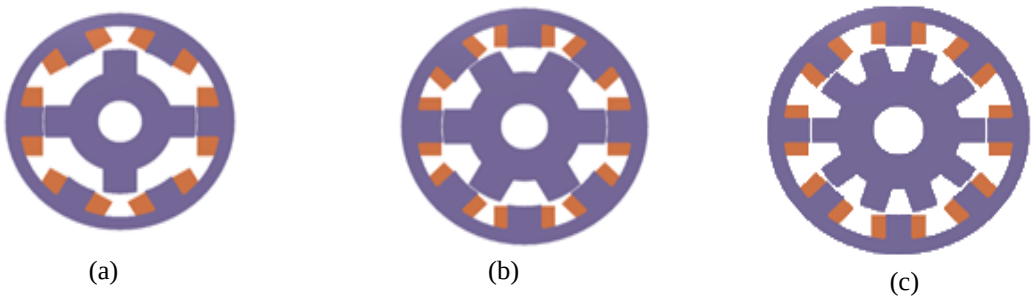


Figure 1. SRM types (a) 6/4 SRM, (b) 8/6 SRM, (c) 10/8 SRM

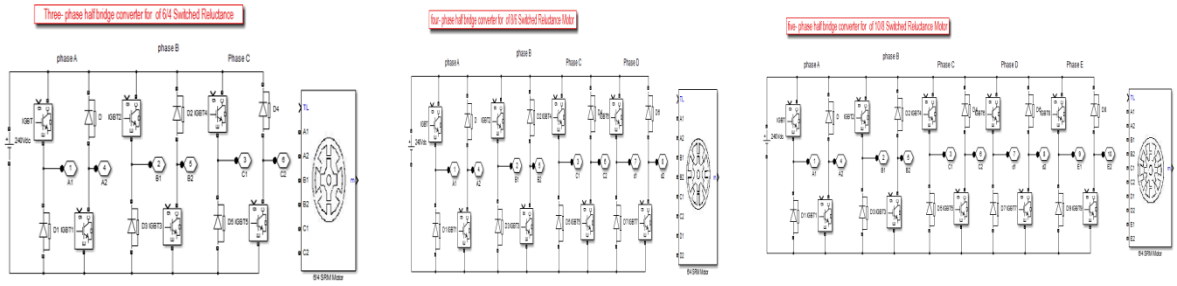
Figure 1(b) shows the 8/6 SRM type construction. In general the 8/6 SRM has an increased of the number of phases employed compared to 6/4 SRM however the motor parameters are keep maintain. The operation principle to produce motion is no different from the 6/4 SRM type. The torque is produced by activating the stator phase which will attract the most adjacent rotor pole pair and then minimize the reluctance of the magnetic path. As a result, constant torque is developed due the activation of consecutive phases of stator in succession. Therefore, the SRM is an electrical motor in which the torque is produced due to the tendency of its movable parts to move till the reluctance of the excited winding is maximized [5]. Figure 1(c) shows the 10/8 SRM type construction [6]-[7]. The motor employed more phase than the previous SRM construction however the parameters are same as the 6/4 and 8/6 SRM types. The principle of torque production is the same as the previous SRM construction.

2. SRM DRIVE TOPOLOGY

The SRM drives have received a great attention for the past two decades'. Several conferences and researches have been conducted to develop new and sufficient drives to control the SRM efficiently and produce the desired output. The power converter has been highlighted in the most research where the SRMs with a different type of power converters has been designed to be fed to the SRM motor [8]. Author in [9] proposed a new topology which use the power inverter to control the SRM motor. However, these drives topologies have their own drawbacks and the most apparent drawback is the Total Harmonics Distortion (THD). Thus, this paper conducts analysis study on the power converter and proposed multilevel inverter drive topology applied to the three type of SRMs.

2.1. Half bridge converter topology

There are numerous converters drives have been developed to be fed to the SRM motor. The most flexible and common topology to be used for the SRM is the half bridge converter. This converter is fed by 240 Vdc sources and requires two switches and two diodes per phase. The turn on and off angles and reference current are kept constant at 45 deg and 75 deg, 200A respectively. The advantage of this converter compared to other type converter is in terms of energy efficiency, where the energy returns from the motor to the source after turn-off of phase switches. Moreover, the control mechanism of this converter is done independently for each phase [10]. As the aim of this paper to investigate the control techniques for three different SRM construction the control circuit of half bridge converter have different configuration for each SRM construction. Figure 2 a, b, c shows half bridge converter to drive the 6/4 SRM Motor, 8/6 SRM motor and10/8 SRM motor respectively.



(a) (b) (c)

Figure 2. Bridge Converter for (a) 6/4 SRM, (b) 8/6 SRM, (c) 10/8 SRM

During conduction periods, the active IGBTs apply positive voltage source to the stator windings to drive positive currents into the phase windings. During free-wheeling periods, negative voltage is applied to the windings and the stored energy is returned to the power DC source through the diodes [11].

2.2. Multilevel inverter

In the past SRM drives, majority of the drives used power converter besides several attempts were made to use inverter that utilize the Voltage Source Inverter (VSI) [9].In this paper new power electronics circuit is used to drive the SRM motor by introducing the multilevel inverter .

The concept of multilevel inverter is to produce multilevel output voltages with less power switching loss and less harmonic distortion. A multilevel inverter can be constructed by connecting a set of single full bridge inverter in series. Each bridge has its own isolated DC source which can be a solar cells or batteries. Theses separated DC sources feeding the multilevel inverter can generate almost sinusoidal waveform voltage. This type of inverter can produce N level voltages (i.e for three level inverter can generate three different voltage outputs +Vdc, 0 and –Vdc).Hence ,the output voltage of an N-level multilevel inverter is the sum of all the individual inverter outputs. [12]-[18]. Figure 3 shows the circuit of the three level inverter.

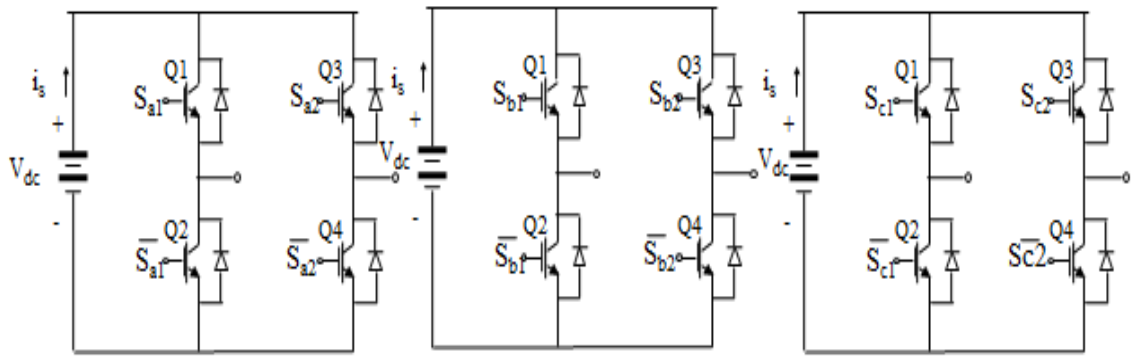


Figure 3. three-level inverter

In this paper three different multilevel circuit is used to drive three different type of SRM motor. Figure 4 and Figure 5 show the circuit of three level inverter 3-phase used to drive the 6/4 SRM motor, 4 phase three-level inverter fed to 8/6 SRM motor and the 5 phase three-level inverter fed to 10/8 SRM motor.

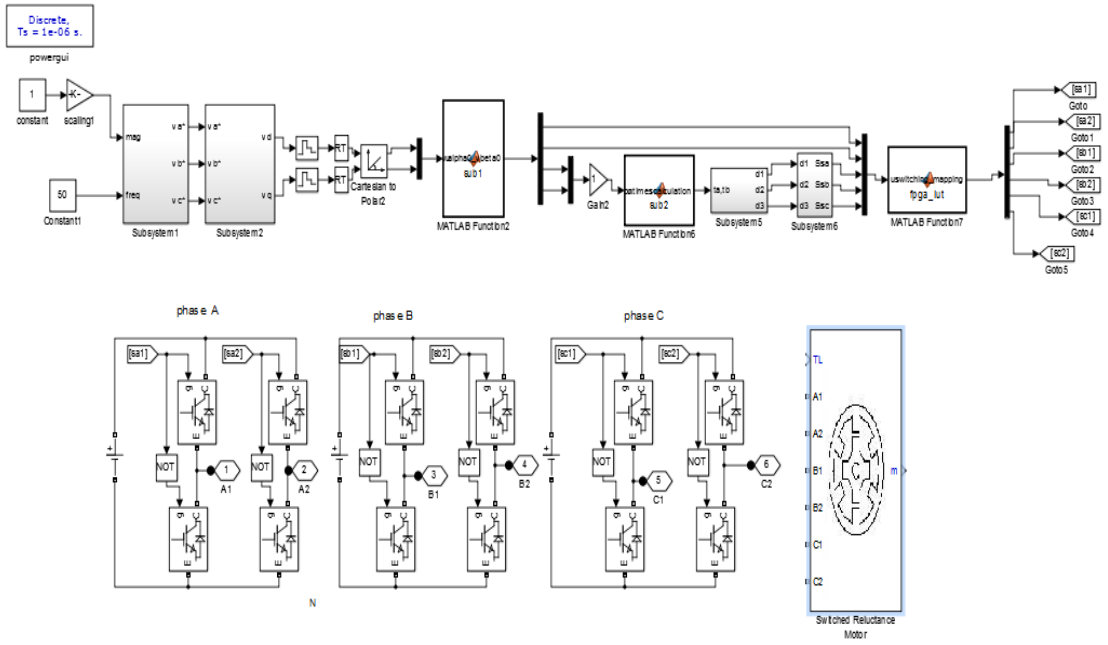
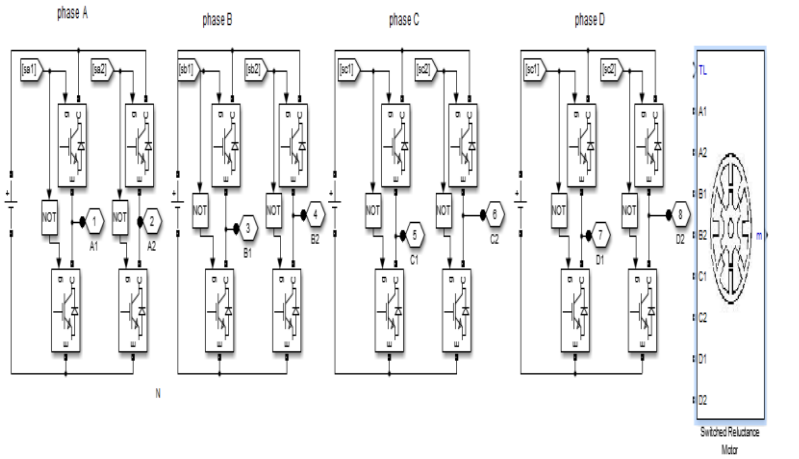
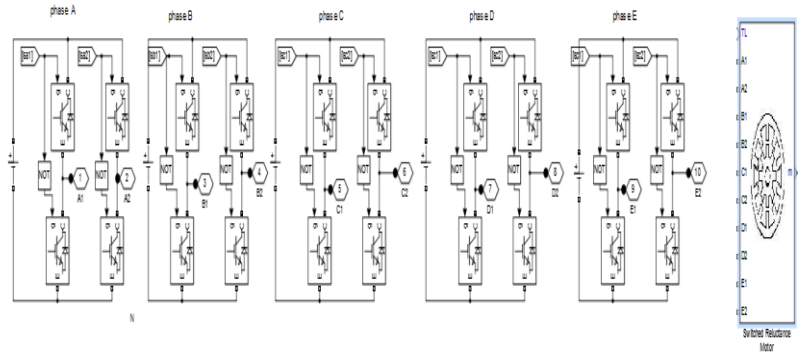


Figure 4. Three-level inverter fed to 6/4 SRM



(a)



(b)

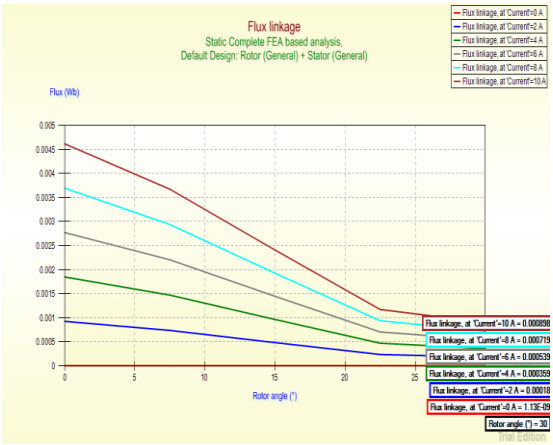
Figure 5. Three-level inverter fed (a) 8/6 SRM, (b) 10/8 SRM

3. SIMULATION RESULTS

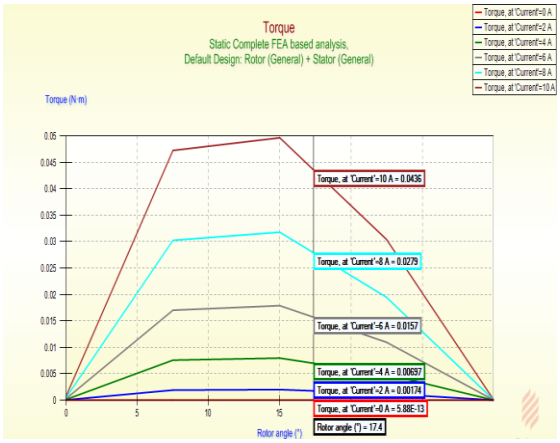
The aim of this paper is to study the flux and torque performance under three different constructions of switched reluctance motor which are the 6/4, 8/6 and 10/8. All the SRMs were constructed in MOTOR SOLVE software with fixed parameters. Then, the SRM drive system were constructed using Matlab/Simulink by utilizing two different drive circuits which are the half bridge converter and the multilevel inverter respectively.

3.1. Results of Motor Solve

Figure 6 (a) shows the output flux line of the SRM using MotorSolve for 6/4, 8/6 and 10/8 SRM with fixed parameters values. Meanwhile, Figure 6 (b) shows the output Torque VS rotor angle which are the same for the three type of SRM. Based on the flux and torque result. The flux linkage analysis for the (SRM) using the static complete FEA analysis ,where the complete analysis for the current is done and shown in different lines, where the lines present the exact value for the flux linkage at each current value.



(a)



(b)

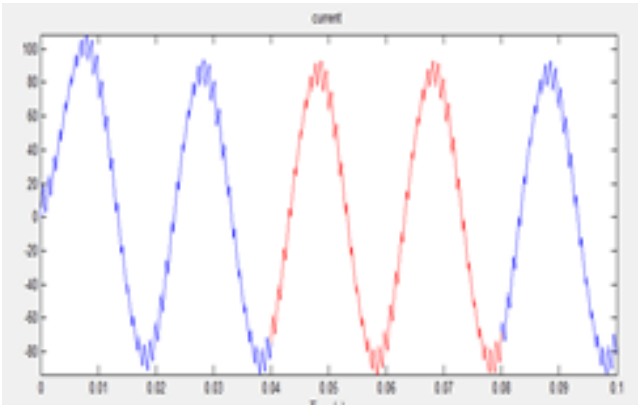
Figure 6. (a) static complete analysis for flux linkage, (b) SRM torque against rotor angle

3.2. Matlab/Simulink Results

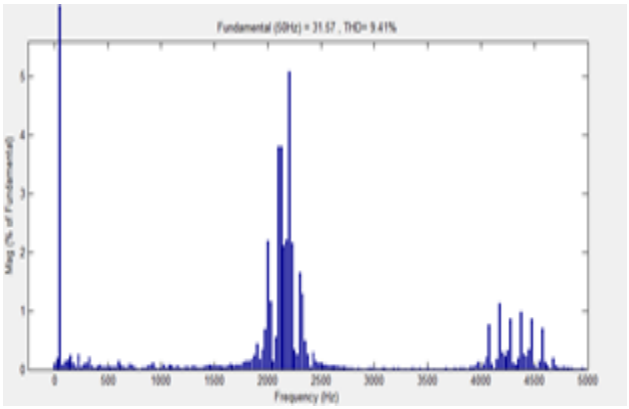
First of all the output of drivers and control circuit is presented and compared in terms of Total Harmonics Distortion THD %.

3.2.1. Half bridge converter topology

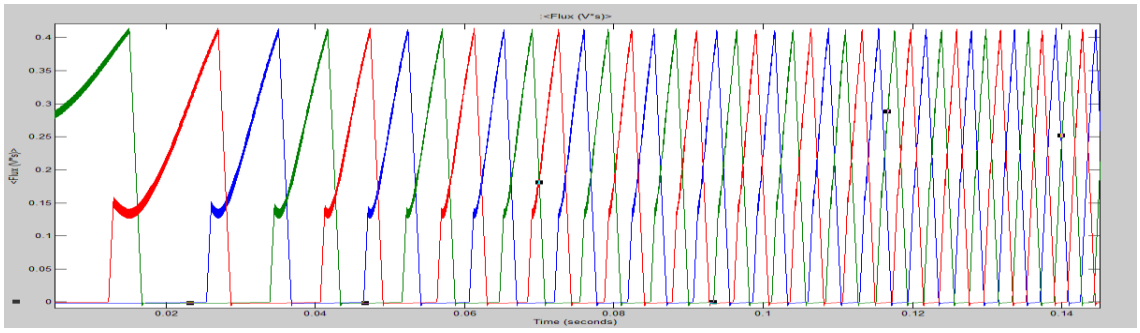
As mentioned earlier the half bridge converter with two IGBT and two free-wheeling diode is fed to the SRM motor. Figure 6 a, b, c, d and d presents the simulation results of half bridge converter fed srm motor.



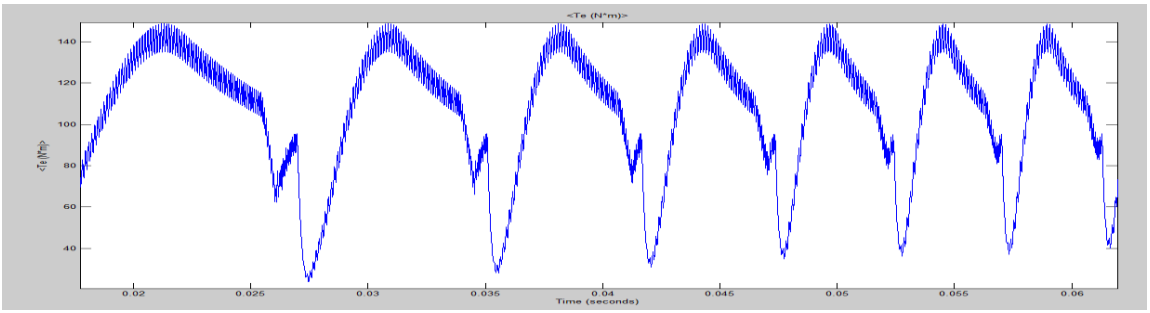
(a) Output current of half bridge convert



(b) THD of current of half bridge converter



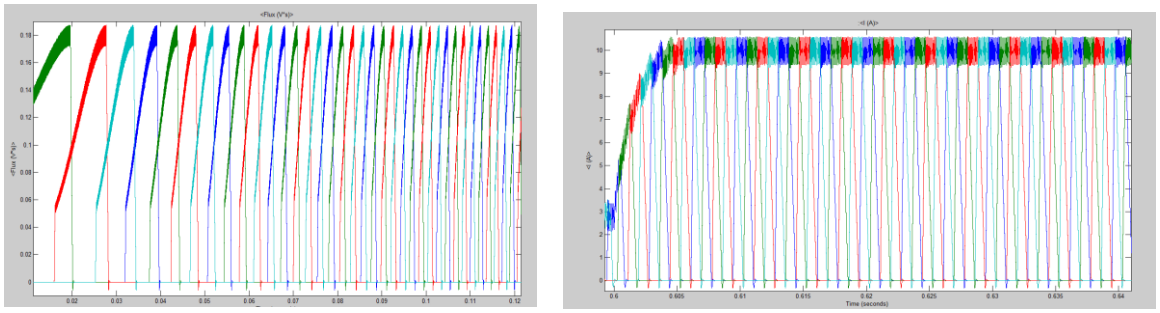
(c) Output flux of 6/4 SRM motor



(d) Output torque of 6/4 SRM fed by half bridge converter

Figure 6. Half Bridge Converter fed 6/4 SRM results

Also Figure 7 and Figure 8 show the 8/6 SRM motor output flux and torque respectively fed by bridge converter.



(a) (b)

Figure 7. (a) output flux of 8/6 SRM motor fed by bridge converter, (b) armature current of 8/6 SRM fed by bridge converter

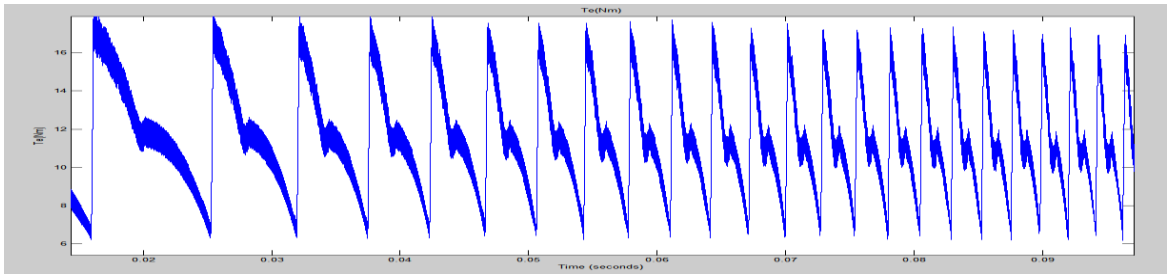


Figure 8. Output torque of 8/6 SRM fed by bridge converter

3.2.2. Multilevel inverter topology

In this paper the three level inverter is used modulated by the space vector. The three level inverter being used having four IGBT in each phase. Figure 9(a) shows the output current of one phase of three level inverter followed by THD current of the same inverter in Figure Figure 9(b).

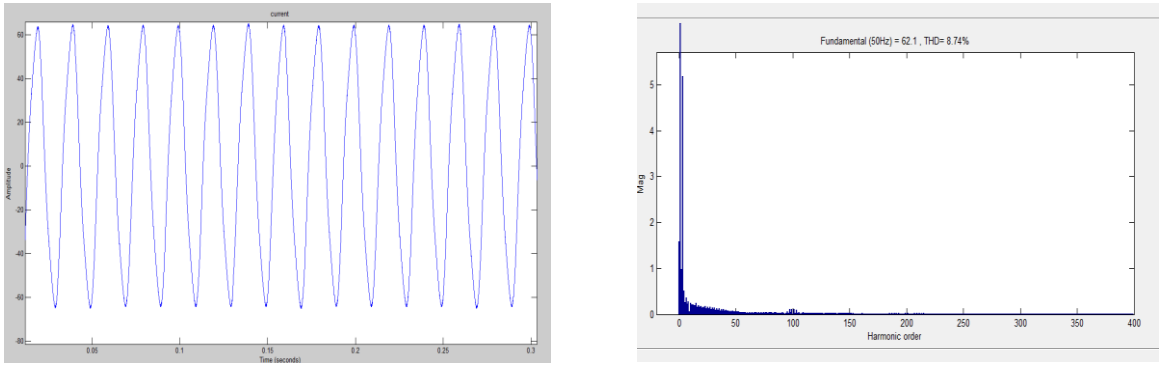
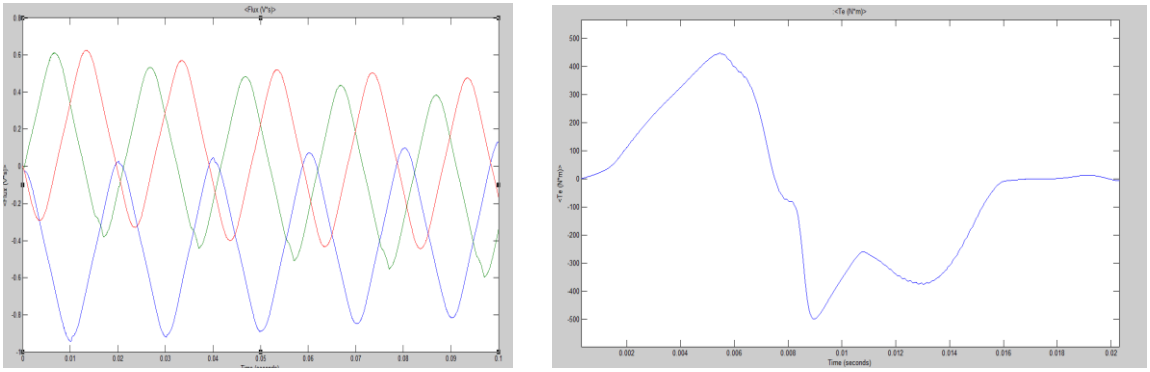


Figure 9. (a) three level inverter output current, (b) current THD of three level inverter

The output flux of and the output torque of 6/4 SRM fed by multilevel inverter are shown in Figure 10a, b.



(a) (b)

Figure 10. output flux of 6/4 SRM fed by multilevel inverter.

Apart from that Figure 11a, b show the output flux and torque of 8/6 SRM motor fed by multilevel inverter.

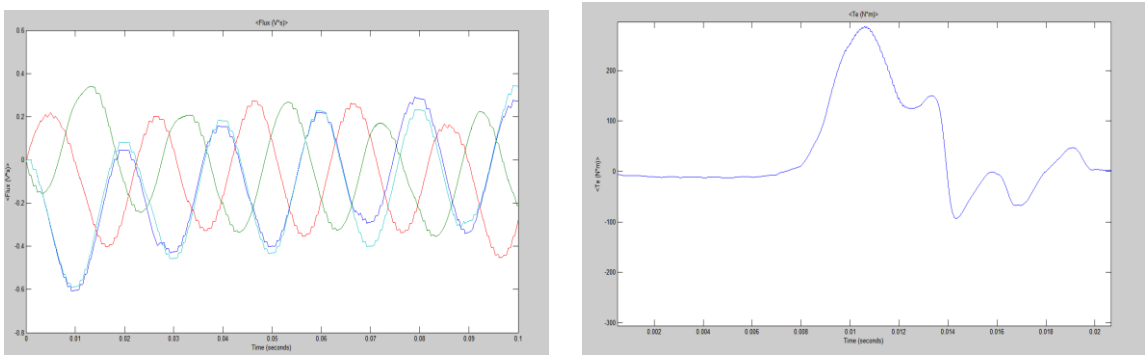


Figure 11. (a) output flux of 8/6 SRM, (b) output torque of 8/6 SRM fed by multilevel inverter.

4. DISSCUSSION

Based on the simulation results obtained, it is clear that the multilevel inverter is best suited for the SRM motor due to the best outputs results produced and the less harmonics contents in output compared to the half bridge converter. Figure 13 shows the comparison between the half bridge converter and multilevel inverter in terms of THD.

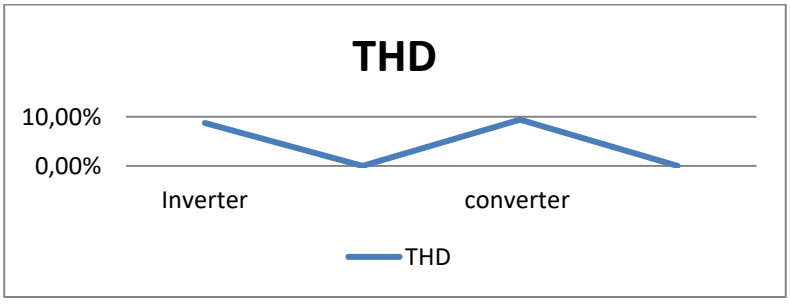


Figure 13. THD comparison of multilevel inverter VS half bridge converter

5. CONCLUSION

This paper presents the performance results of three SRMs known as 6/4, 8/6 and 10/8 performance fed by multilevel inverter and half bridge converter driver circuit. Detailed analysis for the SRM motor

considering different constructions have been conducted. Moreover, for the purpose of comparison with a half bridge converters which have been used to drive the SRM motors, then the results with the multilevel inverter were generated. It was found that the half bridge converters produce more harmonics than the multilevel inverters. Therefore, the multilevel inverter circuit is now recommended as part of the drive circuit as a substitute to the half bridge converter.

6. ACKNOLEGMENT

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